

WHAT IS CLAIMED IS:

1. A fuel injection amount control apparatus of an internal combustion engine, comprising:

a predicted in-cylinder intake air amount calculating unit that predicts an operating state quantity of the engine to be established at a point of time ahead of a current point of time, and calculates a predicted in-cylinder intake air amount that is an amount of intake air drawn into a particular cylinder of the engine during a particular intake stroke, based on the predicted engine operating state quantity, at a point of time before completion of the particular intake stroke of the particular cylinder;

a basic fuel injection amount calculating unit that calculates a basic fuel injection amount for achieving a target air/fuel ratio, based on the predicted in-cylinder intake air amount calculated by the predicted in-cylinder intake air amount calculating unit and the target air/fuel ratio;

an actual in-cylinder intake air amount calculating unit that calculates an actual in-cylinder intake air amount at a point of time after the engine operating state quantity used by the predicted in-cylinder intake air amount calculating unit for calculating the predicted in-cylinder intake air amount with respect to an intake stroke one cycle before the particular intake stroke of the particular cylinder is confirmed, the actual in-cylinder intake air amount calculating unit calculating, as the actual in-cylinder intake air amount, an amount of intake air drawn into the particular cylinder during the intake stroke one cycle before the particular intake stroke, based on the confirmed actual operating state quantity;

a feedforward correction amount calculating unit that calculates a feedforward correction amount based on the predicted in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke and the actual in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke, the feedforward correction amount being determined so as to compensate for an excess or a shortage of the basic fuel injection amount for the intake stroke one cycle before the particular intake stroke, which excess or

shortage is caused by a difference between the predicted in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke and the actual in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke;

a feedforward fuel injection amount calculating unit that calculates a feedforward fuel injection amount by correcting the basic fuel injection amount for the particular intake stroke of the particular cylinder by using the feedforward correction amount;

an air/fuel ratio sensor that detects an air/fuel ratio of an exhaust gas of the engine;

a feedback correction amount calculating unit that calculates a feedback correction amount for reducing a deviation between the air/fuel ratio detected by the air/fuel ratio sensor and an air/fuel ratio of an air-fuel mixture corresponding to the exhaust gas whose air/fuel ratio is detected by the air/fuel ratio sensor, based on the air/fuel ratio of the air-fuel mixture and the detected air/fuel ratio, the air/fuel ratio of the air-fuel mixture being determined based on the feedforward fuel injection amount calculated by the feedforward fuel injection amount calculating unit with respect to a past intake stroke of the particular cylinder during which the air-fuel mixture was introduced into the cylinder;

a final fuel injection amount calculating unit that calculates a final fuel injection amount by correcting the feedforward fuel injection amount calculated with respect to the particular intake stroke of the particular cylinder, by using the feedback correction amount; and

a fuel injector that injects a fuel having the final fuel injection amount into the particular cylinder during the particular intake stroke.

2. The fuel injection amount control apparatus according to claim 1, wherein the basic fuel injection amount calculating unit calculates the basic fuel injection amount by using an inverse model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

3. A fuel injection amount control apparatus of an internal combustion engine, comprising:

a predicted in-cylinder intake air amount calculating unit that predicts an operating state quantity of the engine to be established at a point of time ahead of a current point of time, and calculates a predicted in-cylinder intake air amount that is an amount of intake air drawn into a particular cylinder of the engine during a particular intake stroke, based on the predicted engine operating state quantity, at a point of time before completion of the particular intake stroke of the particular cylinder;

a basic fuel injection amount calculating unit that calculates a basic fuel injection amount for achieving a target air/fuel ratio, based on the predicted in-cylinder intake air amount calculated by the predicted in-cylinder intake air amount calculating unit and the target air/fuel ratio;

a feedforward fuel injection amount calculating unit that calculates a feedforward fuel injection amount by correcting the basic fuel injection amount by using a feedforward correction amount;

a feedforward in-cylinder fuel amount calculating unit that calculates a calculated in-cylinder fuel amount that is an amount of fuel that is supposed to be supplied to the particular cylinder for an intake stroke one cycle before the particular intake stroke on the assumption that a fuel having the feedforward fuel injection amount calculated with respect to the intake stroke one cycle before the particular stroke is injected for the intake stroke one cycle before the particular stroke, the calculated in-cylinder fuel amount being calculated at a point of time later than the intake stroke one cycle before the particular intake stroke;

an actual in-cylinder intake air amount calculating unit that calculates an actual in-cylinder intake air amount that is an amount of intake air drawn into the particular cylinder during the intake stroke one cycle before the particular intake stroke, at a point of time later than a point of time at which the engine operating state quantity used by the predicted in-cylinder intake air amount calculating unit for calculating the predicted in-cylinder intake air amount with respect to the intake stroke one cycle before the particular intake stroke is confirmed, the actual

in-cylinder intake air amount calculating unit calculating the actual in-cylinder intake air amount based on the confirmed actual operating state quantity;

a feedforward target in-cylinder fuel amount calculating unit that calculates a feedforward target in-cylinder fuel amount for achieving the target air/fuel ratio, based on the actual in-cylinder intake air amount and the target air/fuel ratio;

a feedforward correction amount calculating unit that calculates the feedforward correction amount based on the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount, the feedforward correction amount being determined so as to reduce a deviation between the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount;

an air/fuel ratio sensor that detects an air/fuel ratio of an exhaust gas of the engine;

a sensor detected in-cylinder fuel amount calculating unit that calculates a sensor detected in-cylinder fuel amount that is an amount of fuel actually supplied to the particular cylinder for an intake stroke a predetermined number of cycles before the particular intake stroke of the particular cylinder, based on the air/fuel ratio detected by the air/fuel ratio sensor and the actual in-cylinder intake air amount calculated by the actual in-cylinder intake air amount calculating unit with respect to the intake stroke the predetermined number of cycles before the particular intake stroke, wherein an air-fuel mixture introduced into the particular cylinder during the intake stroke the predetermined number of cycles before the particular intake stroke produces a gas whose air/fuel ratio is detected by the air/fuel ratio sensor;

a feedback correction amount calculating unit that calculates a feedback correction amount based on the calculated in-cylinder fuel amount and the sensor detected in-cylinder fuel amount, the feedback correction amount being determined so as to reduce a deviation between the calculated in-cylinder fuel amount calculated by the feedforward in-cylinder fuel amount calculating unit with respect to the intake stroke the predetermined number of cycles before the particular intake stroke, and the sensor detected in-cylinder fuel amount calculated by the

sensor detected in-cylinder fuel amount calculating unit;

a final fuel injection amount calculating unit that calculates a final fuel injection amount by correcting the feedforward fuel injection amount calculated with respect to the particular intake stroke, by using the feedback correction amount; and

a fuel injector that injects a fuel having the final fuel injection amount into the particular cylinder during the particular intake stroke.

4. The fuel injection amount control apparatus according to claim 3, wherein the feedforward in-cylinder fuel amount calculating unit calculates the calculated in-cylinder fuel amount by using a forward model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

5. The fuel injection amount control apparatus according to claim 4, wherein the basic fuel injection amount calculating unit calculates the basic fuel injection amount by using an inverse model of the fuel behavior model representing the behavior of the fuel deposited on the member that forms the intake passage of the engine.

6. The fuel injection amount control apparatus according to claim 3, wherein the basic fuel injection amount calculating unit calculates the basic fuel injection amount by using an inverse model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

7. A fuel injection amount control apparatus of an internal combustion engine, comprising:

a predicted in-cylinder intake air amount calculating unit that predicts an operating state quantity of the engine to be established at a point of time ahead of a current point of time, and calculates a predicted in-cylinder intake air amount

that is an amount of intake air drawn into a particular cylinder of the engine during a particular intake stroke, based on the predicted engine operating state quantity, at a point of time before completion of the particular intake stroke of the particular cylinder;

a basic fuel injection amount calculating unit that calculates a basic fuel injection amount for achieving a target air/fuel ratio, based on the predicted in-cylinder intake air amount calculated by the predicted in-cylinder intake air amount calculating unit and the target air/fuel ratio;

a feedforward fuel injection amount calculating unit that calculates a feedforward fuel injection amount by correcting the basic fuel injection amount by using a feedforward correction amount;

a feedforward in-cylinder fuel amount calculating unit that calculates a calculated in-cylinder fuel amount that is an amount of fuel that is supposed to be supplied to the particular cylinder for an intake stroke one cycle before the particular intake stroke on the assumption that a fuel having the feedforward fuel injection amount calculated with respect to the intake stroke one cycle before the particular stroke is injected for the intake stroke one cycle before the particular stroke, the calculated in-cylinder fuel amount being calculated at a point of time later than the intake stroke one cycle before the particular intake stroke;

an actual in-cylinder intake air amount calculating unit that calculates an actual in-cylinder intake air amount that is an amount of intake air drawn into the particular cylinder during the intake stroke one cycle before the particular intake stroke, at a point of time later than a point of time at which the engine operating state quantity used by the predicted in-cylinder intake air amount calculating unit for calculating the predicted in-cylinder intake air amount with respect to the intake stroke one cycle before the particular intake stroke is confirmed, the actual in-cylinder intake air amount calculating unit calculating the actual in-cylinder intake air amount based on the confirmed actual operating state quantity;

a feedforward target in-cylinder fuel amount calculating unit that calculates a feedforward target in-cylinder fuel amount for achieving the target air/fuel ratio, based on the actual in-cylinder intake air amount and the target

air/fuel ratio;

a feedforward correction amount calculating unit that calculates the feedforward correction amount based on the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount, the feedforward correction amount being determined so as to reduce a deviation between the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount;

an air/fuel ratio sensor that detects an air/fuel ratio of an exhaust gas of the engine;

a feedback correction amount calculating unit that calculates a feedback correction amount for reducing a deviation between a calculated air/fuel ratio and the air/fuel ratio detected by the air/fuel ratio sensor, based on the calculated air/fuel ratio and the detected air/fuel ratio, the calculated air/fuel ratio being determined based on the actual in-cylinder intake air amount calculated by the actual in-cylinder intake air amount calculating unit with respect to an intake stroke a predetermined number of cycles before the particular intake stroke of the particular cylinder, and the calculated in-cylinder fuel amount calculated by the feedforward in-cylinder fuel amount calculating unit with respect to the intake stroke the predetermined number of cycles before the particular intake stroke, wherein an air-fuel mixture introduced into the particular cylinder during the intake stroke the predetermined number of cycles before the particular intake stroke produces a gas whose air/fuel ratio is detected by the air/fuel ratio sensor;

a final fuel injection amount calculating unit that calculates a final fuel injection amount by correcting the feedforward fuel injection amount calculated with respect to the particular intake stroke of the particular cylinder, by using the feedback correction amount; and

a fuel injector that injects a fuel having the final fuel injection amount into the particular cylinder during the particular intake stroke.

8. The fuel injection amount control apparatus according to claim 7, wherein the feedforward in-cylinder fuel amount calculating unit calculates the calculated in-cylinder fuel amount by using a forward model of a fuel behavior

model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

9. The fuel injection amount control apparatus according to claim 8, wherein the basic fuel injection amount calculating unit calculates the basic fuel injection amount by using an inverse model of the fuel behavior model representing the behavior of the fuel deposited on the member that forms the intake passage of the engine.

10. The fuel injection amount control apparatus according to claim 7, wherein the basic fuel injection amount calculating unit calculates the basic fuel injection amount by using an inverse model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

11. A method of controlling a fuel injection amount of an internal combustion engine, comprising the steps of:

predicting an operating state quantity of the engine to be established at a point of time ahead of a current point of time, and calculating a predicted in-cylinder intake air amount that is an amount of intake air drawn into a particular cylinder of the engine during a particular intake stroke, based on the predicted engine operating state quantity, at a point of time before completion of the particular intake stroke of the particular cylinder;

calculating a basic fuel injection amount for achieving a target air/fuel ratio, based on the predicted in-cylinder intake air amount and the target air/fuel ratio;

calculating an actual in-cylinder intake air amount at a point of time after the engine operating state quantity used for calculating the predicted in-cylinder intake air amount with respect to an intake stroke one cycle before the particular intake stroke of the particular cylinder is confirmed, the actual in-cylinder intake air amount being equal to an amount of intake air drawn into the particular

cylinder during the intake stroke one cycle before the particular intake stroke and being calculated based on the confirmed actual operating state quantity;

calculating a feedforward correction amount based on the predicted in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke and the actual in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke, the feedforward correction amount being determined so as to compensate for an excess or a shortage of the basic fuel injection amount for the intake stroke one cycle before the particular intake stroke, which excess or shortage is caused by a difference between the predicted in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke and the actual in-cylinder intake air amount for the intake stroke one cycle before the particular intake stroke;

calculating a feedforward fuel injection amount by correcting the basic fuel injection amount for the particular intake stroke of the particular cylinder by using the feedforward correction amount;

detecting an air/fuel ratio of an exhaust gas of the engine;

calculating a feedback correction amount for reducing a deviation between the detected air/fuel ratio and an air/fuel ratio of an air-fuel mixture corresponding to the exhaust gas whose air/fuel ratio is detected, based on the air/fuel ratio of the air-fuel mixture and the detected air/fuel ratio, the air/fuel ratio of the air-fuel mixture being determined based on the feedforward fuel injection amount calculated with respect to a past intake stroke of the particular cylinder during which the air-fuel mixture was introduced into the cylinder;

calculating a final fuel injection amount by correcting the feedforward fuel injection amount calculated with respect to the particular intake stroke of the particular cylinder, by using the feedback correction amount; and

injecting a fuel having the final fuel injection amount into the particular cylinder during the particular intake stroke.

12. The method according to claim 11, wherein the basic fuel injection amount is calculated by using an inverse model of a fuel behavior model

representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

13. A method of controlling a fuel injection amount of an internal combustion engine, comprising the steps of:

predicting an operating state quantity of the engine to be established at a point of time ahead of a current point of time, and calculating a predicted in-cylinder intake air amount that is an amount of intake air drawn into a particular cylinder of the engine during a particular intake stroke, based on the predicted engine operating state quantity, at a point of time before completion of the particular intake stroke of the particular cylinder;

calculating a basic fuel injection amount for achieving a target air/fuel ratio, based on the predicted in-cylinder intake air amount and the target air/fuel ratio;

calculating a feedforward fuel injection amount by correcting the basic fuel injection amount by using a feedforward correction amount;

calculating a calculated in-cylinder fuel amount that is an amount of fuel that is supposed to be supplied to the particular cylinder for an intake stroke one cycle before the particular intake stroke on the assumption that a fuel having the feedforward fuel injection amount calculated with respect to the intake stroke one cycle before the particular stroke is injected for the intake stroke one cycle before the particular stroke, the calculated in-cylinder fuel amount being calculated at a point of time later than the intake stroke one cycle before the particular intake stroke;

calculating an actual in-cylinder intake air amount that is an amount of intake air drawn into the particular cylinder during the intake stroke one cycle before the particular intake stroke, at a point of time later than a point of time at which the engine operating state quantity used for calculating the predicted in-cylinder intake air amount with respect to the intake stroke one cycle before the particular intake stroke is confirmed, the actual in-cylinder intake air amount being calculated based on the confirmed actual operating state quantity;

calculating a feedforward target in-cylinder fuel amount for achieving the target air/fuel ratio, based on the actual in-cylinder intake air amount and the target air/fuel ratio;

calculating the feedforward correction amount based on the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount, the feedforward correction amount being determined so as to reduce a deviation between the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount;

detecting an air/fuel ratio of an exhaust gas of the engine;

calculating a sensor detected in-cylinder fuel amount that is an amount of fuel actually supplied to the particular cylinder for an intake stroke a predetermined number of cycles before the particular intake stroke of the particular cylinder, based on the detected air/fuel ratio and the actual in-cylinder intake air amount calculated with respect to the intake stroke the predetermined number of cycles before the particular intake stroke, wherein an air-fuel mixture introduced into the particular cylinder during the intake stroke the predetermined number of cycles before the particular intake stroke produces a gas whose air/fuel ratio is detected in the detecting step;

calculating a feedback correction amount based on the calculated in-cylinder fuel amount and the sensor detected in-cylinder fuel amount, the feedback correction amount being determined so as to reduce a deviation between the calculated in-cylinder fuel amount calculated with respect to the intake stroke the predetermined number of cycles before the particular intake stroke, and the sensor detected in-cylinder fuel amount;

calculating a final fuel injection amount by correcting the feedforward fuel injection amount calculated with respect to the particular intake stroke, by using the feedback correction amount; and

injecting a fuel having the final fuel injection amount into the particular cylinder during the particular intake stroke.

14. The method according to claim 13, wherein the calculated in-cylinder

fuel amount is calculated by using a forward model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

15. The fuel injection amount control apparatus according to claim 14, wherein the basic fuel injection amount is calculated by using an inverse model of the fuel behavior model representing the behavior of the fuel deposited on the member that forms the intake passage of the engine.

16. The method according to claim 13, wherein the basic fuel injection amount is calculated by using an inverse model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

17. A method of controlling a fuel injection amount of an internal combustion engine, comprising the steps of:

predicting an operating state quantity of the engine to be established at a point of time ahead of a current point of time, and calculating a predicted in-cylinder intake air amount that is an amount of intake air drawn into a particular cylinder of the engine during a particular intake stroke, based on the predicted engine operating state quantity, at a point of time before completion of the particular intake stroke of the particular cylinder;

calculating a basic fuel injection amount for achieving a target air/fuel ratio, based on the predicted in-cylinder intake air amount and the target air/fuel ratio;

calculating a feedforward fuel injection amount by correcting the basic fuel injection amount by using a feedforward correction amount;

calculating a calculated in-cylinder fuel amount that is an amount of fuel that is supposed to be supplied to the particular cylinder for an intake stroke one cycle before the particular intake stroke on the assumption that a fuel having the feedforward fuel injection amount calculated with respect to the intake stroke one

cycle before the particular stroke is injected for the intake stroke one cycle before the particular stroke, the calculated in-cylinder fuel amount being calculated at a point of time later than the intake stroke one cycle before the particular intake stroke;

calculating an actual in-cylinder intake air amount that is an amount of intake air drawn into the particular cylinder during the intake stroke one cycle before the particular intake stroke, at a point of time later than a point of time at which the engine operating state quantity used for calculating the predicted in-cylinder intake air amount with respect to the intake stroke one cycle before the particular intake stroke is confirmed, the actual in-cylinder intake air amount being calculated based on the confirmed actual operating state quantity;

calculating a feedforward target in-cylinder fuel amount for achieving the target air/fuel ratio, based on the actual in-cylinder intake air amount and the target air/fuel ratio;

calculating the feedforward correction amount based on the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount, the feedforward correction amount being determined so as to reduce a deviation between the calculated in-cylinder fuel amount and the feedforward target in-cylinder fuel amount;

detecting an air/fuel ratio of an exhaust gas of the engine;

calculating a feedback correction amount for reducing a deviation between a calculated air/fuel ratio and the detected air/fuel ratio, based on the calculated air/fuel ratio and the detected air/fuel ratio, the calculated air/fuel ratio being determined based on the actual in-cylinder intake air amount calculated with respect to an intake stroke a predetermined number of cycles before the particular intake stroke of the particular cylinder, and the calculated in-cylinder fuel amount calculated with respect to the intake stroke the predetermined number of cycles before the particular intake stroke, wherein an air-fuel mixture introduced into the particular cylinder during the intake stroke the predetermined number of cycles before the particular intake stroke produces a gas whose air/fuel ratio is detected in the detecting step;

calculating a final fuel injection amount by correcting the feedforward fuel injection amount calculated with respect to the particular intake stroke of the particular cylinder, by using the feedback correction amount; and

injecting a fuel having the final fuel injection amount into the particular cylinder during the particular intake stroke.

18. The method according to claim 17, wherein the calculated in-cylinder fuel amount is calculated by using a forward model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.

19. The method according to claim 18, wherein the basic fuel injection amount is calculated by using an inverse model of the fuel behavior model representing the behavior of the fuel deposited on the member that forms the intake passage of the engine.

20. The method according to claim 17, wherein the basic fuel injection amount is calculated by using an inverse model of a fuel behavior model representing the behavior of a fuel deposited on a member that forms an intake passage of the engine.